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ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO H. M. ASTRONOMER, DR. DAVID GILL.

BY GEORGE C. PARDEE.

Following the custom established by my predecessors, it becomes my duty this evening to make public announcement of the award of the Bruce Gold Medal of the Society.

I take great pleasure in stating that the award for this year, by unanimous vote of the Board of Directors, was made to H. M. Astronomer at the Cape of Good Hope, Dr. DAVID GILL.

Before proceeding to give the Society an account of Dr. GILL'S "distinguished services to astronomy," which so eminently entitle him to this mark of our consideration, it may not be inappropriate to call attention to the catholicity of science, and of astronomical science in particular, as exemplified in the first three awards of the Bruce Medal. Science recognizes no distinction of nationality; and while as Americans we are proud to think that an American astronomer was found worthy to be honored as our first medalist, we last year gladly recognized the right of the man who "to-day stands at the head of German astronomy" to take rank with him, and now make no less welcome the distinguished representative of English astronomy, whose work we honor to-night.

I am indebted to Professor R. G. AITKEN, of the Lick Observatory, for the collection and arrangement of the following facts concerning the astronomical work of our eminent medalist.

In a lecture delivered at the Royal Institution in 1884, Dr. GILL, after speaking of the fascination sidereal astronomy has ever had for the mind of man, of the questions without number that crowd upon the mind in contemplating the distances of space,

and of the little progress that has been made in the solution of these problems, used the following language :—

"Human knowledge in the slow developing phenomena of sidereal astronomy must be content to progress by the accumulating labors of successive generations of men; progress will be measured for generations yet to come more by the amount of honest, well-directed, and systematically discussed observation than by the most brilliant speculation; and in observation, concentrated systematic effort on a special thoughtfully selected problem will be of more avail than the most brilliant but disconnected work."

These few words may be taken as his scientific creed or confession of faith. Certainly his work forms a most significant commentary on its value. Born in Aberdeenshire, Scotland, in 1843, and educated at Aberdeen, he became Lord LINDSAY'S assistant at the Dun Echt Observatory; and by him was sent to Mauritius, in 1874, to observe the transit of *Venus*. Dr. GILL took advantage of this opportunity to test practically his modification of the method of determining the value of the solar parallax from observations of a minor planet, first proposed by Dr. GALLE, of Breslau. Thus his first extensive piece of work was an important contribution to the determination of this fundamental constant of astronomy.

The next was the determination of the same constant from heliometer observations of the planet *Mars* at the opposition of 1877, a work for which the Royal Astronomical Society awarded him its gold medal in 1882. The last great piece of work published by him is his determination of this same constant from observations of the minor planets, *Iris*, *Victoria*, and *Sappho*, a work resulting in a value of this quantity which is generally admitted to be the most exact known, and one which, in all probability, will suffer but slight correction from future investigations. A better example of "concentrated systematic effort on a special thoughtfully selected problem" and of its "avail" it would be hard to find.

The efforts of astronomers to arrive at the value of the solar parallax, or its equivalent, the mean distance of the Earth from the Sun, form one of the most interesting chapters in the history of astronomy. From the earliest times it has engaged the minds of men; for a knowledge of it is necessary to give us any true conception of the actual dimensions of the solar system, of the masses and distances of the planets, and, ultimately, of the fixed stars. We cannot take time to recount the many solutions that

have been attempted of this "the noblest problem in astronomy," as Sir GEORGE AIRY describes it. We must content ourselves with quoting Dr. GILL's own remark, that "Every attempt has shown some short-coming in the previous one, and the result has always been to mark a new era of progress in the science, to create a fresh interest in its pursuit, and to stimulate the invention of more refined instruments and methods."

In 1867, NEWCOMB, from a discussion of all the available data, derived the value 8″.848, corresponding to a distance of about 92,370,000 miles. This result was generally adopted by astronomers in their calculations, though no one was satisfied that it was sufficiently near the truth to make further investigation unnecessary. The question was, What method should be adopted to secure the most reliable result in the shortest time? Lord LINDSAY and Mr. GILL proposed to combine the suggestions of Dr. GALLE, of measuring the displacement of an asteroid among the stars at the time of opposition, with Sir GEORGE AIRY'S, of employing what is now known as the diurnal method of observation, and to substitute the heliometer for the ordinary equatorial and micrometer.

The fact that *Juno*, one of the nearer asteroids, came to opposition at the time when they planned to be at Mauritius to observe the transit of *Venus* in 1874, seemed to offer a favorable opportunity to test the practical value of this new method. Owing to unfortunate delays in the arrival of the expedition at Mauritius, the series of observations was only one-third as extensive as had been planned, and, in consequence, the observers themselves did not "attach high importance to the value of the parallax deduced." The *important* result of this attempt was the high degree of precision which was found to attend the heliometer measures, confirming their previous conclusion, "that it is possible by means of the heliometer to determine the place of a minor planet relative to two stars (or if within a distance of 1000″, to one star) with a probable error of less than 0″.01." This led Dr. GILL to hope that the same method might be employed in observations on *Mars* at the very favorable opposition in 1877 with results of greater precision than could be attained by any other known method.

Through the liberality of Lord LINDSAY and several other members of the Royal Astronomical Society, and with the aid of grants from the Royal Society and from the Royal Astronom-

ical Society, Dr. GILL was enabled to take the heliometer used in the *Juno* observations, together with the necessary subsidiary instruments, to the island of Ascension to put his plan to the practical test. The method of observation was similar to that employed in the former attempt, with some modifications suggested by the experience then gained. It consisted, in brief, in observing the position of *Mars* with reference to selected stars as early after sunset in the evening and as late before sunrise in the morning as practicable, thus measuring double the parallactic displacement of the planet. The accuracy attainable in these measures is so great that it was desirable to have the positions of the comparison-stars fixed with all possible precision. To this end these stars were carefully reobserved at thirteen of the principal observatories of the world.

The final result of this admirable piece of work was to fix the value of the solar parallax at $8''.78 \pm 0''.012$. At the time, this ranked as one of the best determinations of this constant that had been made, and, as we have said, the work won for its author the gold medal of the Royal Astronomical Society. But in his memoir, Dr. GILL himself showed that the result might be subject to a possible small correction from difficulties peculiar to observations of *Mars*, and again stated with emphasis that the most promising method to insure an accurate result was by the heliometric observation of such of the minor planets as approached nearest to the Earth.

The exceptionally favorable oppositions of *Iris* in 1888, and of *Victoria* and *Sappho* in 1889, afforded an excellent opportunity to repeat the observation, and by that time, too, a number of very powerful heliometers had been constructed, several of them possessing refinements of adjustment planned by Dr. GILL himself. Having secured assurances of co-operation in the observations from a number of heliometer observers, — especially from Dr. ELKIN, of Yale, and from Dr. AUWERS, of Berlin, — Dr. GILL issued a carefully planned programme of work which made provision for "the complete determination and elimination of every preconceivable form of systematic error." This was fully carried out; concerted observations of the three asteroids were made at the Cape of Good Hope, in the southern hemisphere, and at New Haven, Göttingen, Leipzig, Bamberg, and Oxford, in the northern; the comparison-stars were carefully reobserved on the meridian-circles of the principal observatories of the world; and

the whole mass of material reduced and discussed with every refinement of method known to modern astronomy.

It is difficult to form an adequate conception of the amount of labor involved in such a piece of work. Aside from the careful observations of the phenomena themselves, thousands of observations most trying to the eyes are necessary to determine with accuracy the errors of the instruments, (Dr. GILL, for example, made about fifty thousand observations, the equivalent of nine months' work at two hours a day, to determine the division-errors of the scales of his heliometer,) and when the observation material is at last all collected, the real work may be said to have just begun. To handle such an enormous mass of data, to subject it to the minute and detailed analysis necessary to eliminate all possible forms of error, to reduce it to a manageable set of normal equations, and, finally, to determine the most probable values of the quantities sought, demands not only mathematical judgment and skill of the highest order, but also patient tenacity of purpose and a tremendous capacity for work.

While the determination of the definitive positions of the comparison-stars from the meridian-circle observations was due to Dr. AUWERS, and the discussion of the results for *Iris* to Dr. ELKIN, the plan of the entire work was Dr. GILL's. He discussed the results for *Victoria* and *Sappho*, made the final revision of the work, and is responsible for the result. His conclusion is that the value of the solar parallax from these observations is 8″.802, with a probable error of ±0″.005, and that this may be regarded as absolutely reliable within such limits as are indicated by the value of its probable error. This means that the distance from the Earth to the Sun is known to within about fifty or sixty thousand miles. Or, to illustrate the accuracy of the result in another way, the outstanding error may be represented by the angle subtended by a foot-rule at a distance of a little over seven thousand miles.

It must not be supposed that Dr. GILL's entire time has been devoted to investigations of the solar parallax. Although his work in this connection has been sufficient to insure him a very high rank among astronomers, it has been far from completely engrossing his attention. On his appointment as H. M. Astronomer at the Cape of Good Hope in 1879, Dr. GILL took with him the heliometer used in his observations of *Juno* and *Mars*, and, in the years 1881–83, instituted a series of observa-

tions to determine the value of the annual parallax of nine of the more interesting southern stars. In this work he had the assistance of Dr. ELKIN, who was his guest during those years. "These investigations constitute the first successful attempt made by extra-meridian observations, to determine stellar parallax in the southern hemisphere." The results for the nine stars measured are accepted generally by astronomers. This work has been, and is being, continued with the new heliometer, by Dr. GILL and other observers under his direction, the "great cosmical questions to be answered" being "not so much what is the precise parallax of this or that particular star, but (1) what are the average parallaxes of those of the first, second, third, and fourth magnitude, respectively, compared with those of lesser magnitude? (2) what connection does there subsist between the parallax of a star and the amount and direction of its proper motion? or can it be proved that there is such a connection or relation? From such data we should probably be able to determine the law of absorption of star-light in space, and be provided with the facts at present wanting for determining with more precision the amount and direction of the motion of the solar system in space." A second memoir on this subject, giving the parallaxes of thirteen additional stars, is now nearly completed.

While work in these two allied fields of research may be regarded as the more important of Dr. GILL'S personal contributions to the advancement of astronomy, we must not fail to call attention to the great services he has rendered in the past twenty-one years as Director of the Observatory at the Cape of Good Hope, and to the important enterprises he has inaugurated or been intimately associated with. Struck with the splendor of the great comet of 1882, he secured, with the aid of a local photographer, several photographs of it. The number and sharp definition of the star-images on these plates led him to suggest the use of photography for star-charting in general, and in particular for extending the Bonn Durchmusterung from $-23°$ to the South Pole. Without reviewing the history of the movement that led finally to the assembling of the Astrophotographic Congress and its decision to photograph the entire heavens on a uniform system, we may note that Dr. GILL took an important part in all the proceedings; and that the Cape Observatory has practically completed the series of photographs needed in the

zone from — 40° to — 52° Declination. The work of measuring up these plates is now in progress under Dr. GILL's supervision and on engines built from his designs.

But before the Astrophotographic Congress met, Dr. GILL had decided to carry out his idea of a photographic Durchmusterung of the heavens south of — 23° Declination; and by the year 1889 the necessary plates had all been taken — in considerable part at his private expense. Professor KAPTEYN, of Gröningen, volunteered to undertake the labor of measuring these plates, the pressure of other work making it impossible to measure them at the Cape Observatory. Two volumes of this great work, containing the places and magnitudes of more than 316,000 stars between — 19° and — 52° Declination, have already been distributed, and the third, which will complete the work, is nearly ready.

Of the ordinary administrative duties pertaining to a position such as Dr. GILL holds, we need here say nothing more than that the building up of a great observatory (and such the one at the Cape of Good Hope has become under his direction) would of itself be a task sufficient for a life-work. When we add that in addition to all else, Dr. GILL has found time to design the instruments and methods employed in the geodetic survey of South Africa, to plan and control the field operations, and personally to superintend and take part in the measurement of several of the base-lines, we are obliged to admire his capacity for work almost as much as his ability as an observer and a mathematician.

This brief sketch, imperfect as it is, will, I think, serve to show that Dr. GILL's services to astronomy have been amply adequate to entitle him to the highest honor we can bestow upon him,— the award of the Bruce Gold Medal.

Mr. Secretary, in the absence of our medalist, I hand the award to you, to transmit to Dr. GILL, with the assurances of the heartiest wishes of this Society that his future labors may be rewarded with the distinguished success that has crowned them in the past.

March 31, 1900.